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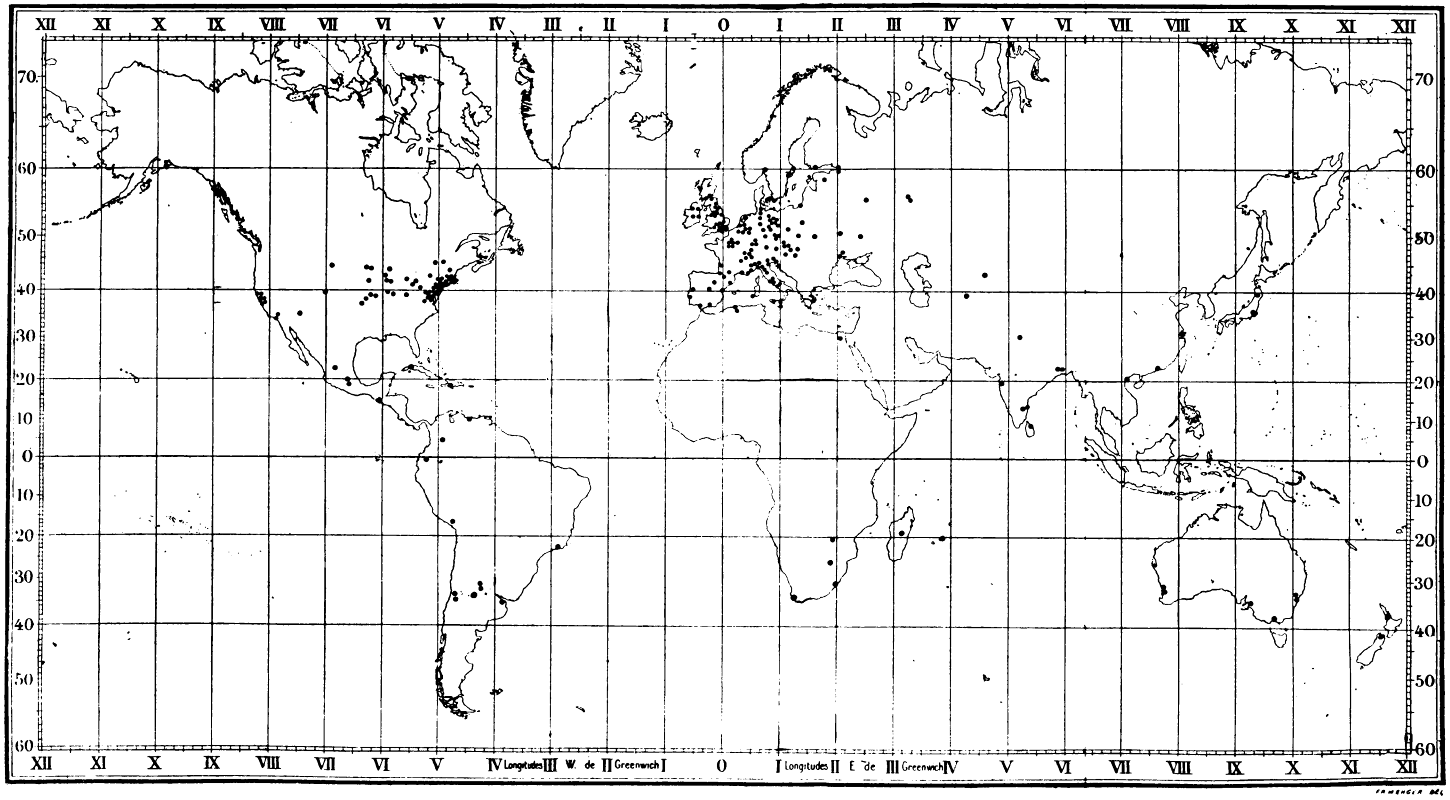
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FIGURE I. DISTRIBUTION OF THE PRINCIPAL OBSERVATORIES OF THE WORLD

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

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ASTRONOMICAL PROBLEMS OF THE SOUTHERN HEMISPHERE.

BY HEBER D. CURTIS.

It is a natural result of the more recent development of the civilizations of the southern hemisphère that advances in the science of astronomy should likewise be less extensive than those made by the parent civilizations of the northern hemisphere. From the nature of the case, the southern hemisphere possesses relatively few astronomical records which can compare, in point of time, with those obtained for the northern skies during the last two centuries; and in the past, but to a less extent to-day, no small part of the progress made in mapping and studying the southern skies has been made by expeditions from the older foundations of Europe and America.

Probably the first observatory south of the equator which can be described as of a permanent character was that founded by Sir THOMAS BRISBANE in Paramatta, New South Wales, as a private observatory, in 1821; its period of activity extended over about ten years, and it was later incorporated with the Observatory of Sydney. An observatory was founded in Buenos Aires in 1822, but its period of activity was very short. Although the Observatory of the Cape of Good Hope was founded in 1820, its activity did not commence till 1829, the date of its completion; the extremely valuable and extensive work carried on here during the eighty years past give to it the unchallenged rank as the oldest permanent astronomical foundation in the southern hemisphere. At a later date we find the foundation of the Observatory of Santiago in 1856;

Melbourne, founded in Williamstown, Victoria, in 1853 and transferred to Melbourne in 1861; Adelaide, established in 1854; Córdoba, 1870; Arequipa in 1891, and others of more recent date. Among the early expeditions of a temporary character may be noted the visit of HALLEY to St. Helena in 1677; later we come to the appearance of the first large, systematic catalogue of the southern stars by LACAILLE as a result of his stay of four years at the Cape of Good Hope in the years 1751-55; the noteworthy investigations made at the same spot by Sir JOHN HERSCHEL from 1834 to 1838; the expedition sent to Santiago under charge of GILLISS in 1849; and others of more recent date to which attention will be called later.

The observatories in the southern part of the north temperate zone can extend their investigations in many lines of astronomical research to a distance of thirty degrees to the south of the celestial equator without great difficulty or loss of accuracy, but from this limit to the south pole we have a region amounting to about one fourth of the entire sky which, relatively to the northern skies, was almost as much a *terra incognita* seventy-five years ago as was Central Africa at the same date, and which to-day contains many virgin fields which offer rich returns to the exploring astronomer.

In the first great subdivision of astronomy, the astronomy of position, whose field is primarily the determination of the accurate positions of the fixed stars, the observed changes in these positions are so minute that the element of time becomes the most important factor to enable conclusions to be drawn from a given mass of observations as to the proper motions of the stars and the structure of the sidereal universe as a whole. Because of this relatively short time-factor since the earlier exact observations of the positions of the southern stars, the astronomy of precision of the southern hemisphere can not yet compete with the results from the northern heavens. Sir DAVID GILL has said, and there is doubtless no more competent authority to pronounce upon this point than he, that the state of our knowledge of the exact positions of the stars of the southern hemisphere is at least a century behind that of the northern hemisphere. Nevertheless, if we consider the results already secured in the exact cartography of the southern skies, and take into consideration also the researches in this field at present well under way, we may safely reach the conclusion that the coming twenty years will render our knowledge of southern star positions very little inferior to those of the northern skies, always excepting, in this conclusion, the disadvantage arising from the lack of early observations, a lack which will necessitate the accumulation of results for many years before our knowledge of southern proper motions can equal that of the northern stars.

In this task of bettering our knowledge of exact star positions in the southern hemisphere it is doubtless superfluous to mention here the excellent work that has been done in the past and is now in progress at a number of southern observatories, especially the extensive results from Córdoba and the Cape of Good Hope. In 1865 the Astronomische Gesellschaft undertook the extensive task of mapping, by means of exact meridian observations, all the stars in the sky down to the ninth magnitude. This work for the northern hemisphere and for some distance south of the celestial equator is now practically completed, and the work is advancing favorably for the more southerly portions of the sky at the observatories of Madras, Melbourne, and the Cape.

One of the most important programs in connection with the astronomy of precision of the southern hemisphere is that inaugurated last year under the auspices of the Carnegie Institution of Washington. It has for its object the measurement of the accurate positions of about twenty-five thousand stars in the southern skies in accordance with the system of Professor Boss, of Dudley Observatory. The instrument employed is the meridian circle of the Dudley Observatory, which has been used in the past for exactly similar work in the northern skies. The constants, graduation errors, etc., of this instrument have been so thoroughly investigated that doubtless no more efficient instrument exists to-day for this class of work. By the use of the same instrument, the same system of reductions, and to a certain extent even the same observers, it seems probable that the results of this program will afford us a far more exact binding together of the northern and southern skies in one homogeneous system than we possess to-day. The site has been selected at San Luis in the Argentine Republic. Professor TUCKER, of the Lick Observatory, is in charge of the Carnegie Observatory at San Luis, and recent advices state that the site seems to be a very favorable one for this class of work; it is hoped that the number of clear nights will average two hundred per year. The project involves about three years' work, and about seven observers and assistants are employed. Observations will be made throughout every clear night, "from sun to sun," with supplementary observations by day, and at this time the work of the observatory is doubtless in full swing.

In the years 1885-91, under the direction of Sir DAVID GILL, the Observatory of the Cape of Good Hope undertook an extensive photographic map of the southern skies, from declination — 19° to the south pole. The measurement of the positions of the stars on these plates was carried through by the disinterested and self-sacrificing labors of Professor KAPTEYN, and the publication in 1900 of the third and concluding volume of the great "Cape Photographic Durchmusterung" marked the completion of this monumental task. It contains the positions of 454,875 stars nearly to the tenth magnitude, and the positions are accurate to about one second of arc. It is an epoch-making work in the cartography of the southern heavens; in fact, until the completion of the "Astrographic Catalogue" no such complete and systematic photographic catalogue exists for the northern hemisphere. Naturally it can not compete, however, with the accuracy of the "Astrographic Charts"; those from Helsingfors, for example, having the small probable error of 0.″11 for the mean of two measured star images.

Without doubt, however, the greatest problem in the cartography of the southern skies which awaits the observatories of the southern hemisphere is the completion of their respective shares in the great photographic map of the heavens mentioned above, which was inaugurated at the International Conference in Paris in 1887. As is well known, this plan, in its entirety, involved the construction of a photographic map of the entire sky down to the fourteenth stellar magnitude, for which about twenty-two thousand plates were to be taken, and the total number of the stars registered on the plates would probably reach twenty million. Supplementary to these charts the plan contemplated the publication of a great catalogue of perhaps two million stars down to the eleventh magnitude, based on plates of shorter exposure time. The task was apportioned among eighteen observatories in the two hemispheres. The observatories south of the equator which possess photographic equatorials of the uniform type adopted for the work are those at La Plata, Córdoba, the Cape, Santiago, Perth, Melbourne, and Sydney. It was proposed that the entire work be repeated in one hundred years. But so vast is the scope of this program that even in the northern hemisphere this project, whose value for the astronomy of position of the future can scarcely be over-estimated, has by no means made the progress anticipated for it at the time of its inception. Owing to the cost, only a few of the co-operating observatories have agreed to publish the great maps, and among southern observatories Perth has decided to take only the plates to the eleventh magnitude and to publish the resulting catalogue. Perth has taken all the plates in its zone, and has commenced the measures for the Catalogue. The section apportioned to the Cape of Good Hope is now nearly completed, both as to the taking of the plates and their measurement, and rapid progress is being made at Sydney, Melbourne, and Córdoba. Up to 1908 nothing had been done at La Plata or Santiago, though Dr. RISTENPART, recently appointed director of the National Observatory at Santiago, will make every effort for the prompt completion of the zone assigned to him; the work of taking the plates has already been begun under the direction of Dr. ZURHELLEN. It would seem that the publication of the costly maps might well be abandoned, for the plan adopted at Oxford of publishing only the co-ordinates of the stars would be far cheaper and fully as useful.

Excellent work has been done in determination of stellar parallax at the Cape of Good Hope, but the difficult field of work which has for its aim the determination of the distances of the stars by the heliometer or modern photographic methods is still practically untouched in the southern hemisphere. Parallaxes of only seventeen stars south of declination — 30° have been published, while north of this limit about three hundred parallaxes have been determined, many of them a number of times, by different observers and different methods.

In the interesting field of double stars, as is well known, HERSCHEL discovered many systems in the southern skies, and modern observers, as INNES, TAYLOR, and others, have materially augmented this number. During the past decade Professors AITKEN and HUSSEY have been making a very complete and systematic search for such doubles in the northern celestial hemisphere, with the result that several thousand new doubles have been discovered, many of them of great interest. They have reached the conclusion that at least one in every eighteen stars brighter than the ninth magnitude is a visual binary system. To these results we must add the evidence of the spectroscope that one in every five or six of the stars thus far examined is a spectroscopic double, and we have facts whose importance it is scarcely possible to over-estimate in their bearing on our theories of stellar evolution. Such systematic researches for the discovery of visual doubles are most urgently needed in the southern skies to round out the program which these astronomers have now nearly completed for the northern portions of the heavens. In this regard there is no doubt that the southern sky offers one of the richest and most promising fields of research existing to-day. BURNHAM'S great "Catalogue of Double Stars," recently published by the Carnegie Institution, includes 13,665 pairs of stars and extends to south declination 31°. This eminent authority estimates that a century must pass before sufficient data can be collected to make a similar catalogue necessary for the southern hemisphere. INNES'S "Reference Catalogue of Southern Double Stars"[1] contains 2,191 pairs between the equator and the south pole, but of this number about 925 are between the equator and BURNHAM'S southern limit, nearly all of which have been discovered by observers in the northern hemisphere. A comparison of the number remaining, south of —31°, with the results from the northern skies will show clearly that there may well be two thousand double stars brighter than the ninth magnitude at present awaiting discovery in the southern hemisphere, to say nothing of the need for additional researches on the pairs already known.

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[1] Cape Annals, Vol. II, part II, 1899.

During the past ten years systematic observations have been made at six special stations in the northern hemisphere to study the small oscillations of the axis of the earth known as the variation of latitude. These stations are located at Mizusawa, Japan; Tschardjui, Asiatic Russia; Carloforte, Italy, and at Gaithersburg, Maryland; Cincinnati, Ohio, and Ukiah, California; and are all situated almost exactly on the parallel of north latitude 39° 8′. In 1905 the association which has this research in hand, Das Centralbureau der Internationalen Erdmessung, decided to extend this series of observations to the southern hemisphere, and the plans at first contemplated three stations: in Sydney, Australia; Capetown, Africa; and Santiago, Chile. It was pointed out, however, by Dr. HELMERT that better results could be secured, as far as the evaluation of the so-called Kimura-term in the latitude equation was concerned, by two stations placed as exactly as possible on opposite sides of the earth. Accordingly, after correspondence with authorities in Australia and the Argentine Republic, two sites were chosen in 1905 which satisfy this condition, and are, in addition, admirably situated as regards climatic advantages. Both are in south latitude 31° 55′ 15″, and differ 179° 36′ in their longitudes. The Australian installation is in charge of Dr. HESSEN, formerly of Berlin, and is located at Bayswater, West Australia, about four miles from Perth, the capital. The Argentine station is under the direction of Dr. LUIGI CARNERA, formerly occupied in similar observations at Carloforte, and is located at Oncativo, about forty-five miles from Córdoba.

Both of these stations commenced observations in 1906, and the work has been prosecuted with great energy since that date.[1] The results thus far secured are enabling us to draw more accurate conclusions with regard to these supplementary, exceedingly minute movements of the Earth's axis.

The formula for the variation of latitude is ordinarily expressed by the equation

$$\phi - \phi' = x \cos \lambda + y \sin \lambda + z,$$

where x and y are the components of the variation in the planes of zero longitude and that perpendicular to this, while the term z, called the Kimura-term from the Japanese astronomer who suggested its introduction, denotes that part of the variation which is common to all the stations, corresponding to an apparent movement of the center of gravity of the earth toward one or the other pole. The results from the northern stations have revealed the interesting fact that the value of z is periodic, with a period of one year, reaching its zero values about March 9th and September 12th, and its maximum and minimum values on June 10th and December 10th, these points coming, then, about ten days before the solstitial points. The preliminary results from the southern stations coincide almost exactly with those from the northern stations with respect to the magnitudes of x and y, and show, in addition, that the value of the z-term is of the same magnitude and algebraic sign as that derived from the northern results. This z-term is very small, oscillating only 0.″046 on each side of the mean, which, if real, would correspond to a movement of the center of gravity of the earth of about four and a half feet toward the north or the south pole. The temptation is very strong to seek a meteorological explanation for this small shift of the plane of the equator. The accumulation of snow and ice at one pole, together with the corresponding diminution at the other pole due to the melting in the summer season, would be perhaps sufficient to explain the shift, but, if this were the true and only explanation, it is difficult to see why the maxima and minima do not follow the solstitial points by a considerable interval of "lag," instead of preceding them by about ten days.[1] Moreover, the quantities involved are so extremely minute, such transcendental care is necessary in arranging and making the observations, and such pains to exclude in the investigation all possible sources of systematic error, that astronomers are by no means in accord as to the real existence of the z-term. BISKE has shown that a variation similar to that afforded by the z-term could arise as a result of inaccuracies in the adopted value of the solar nutation, and that future progressive changes in this value could result from similar slight errors in the adopted value of the lunar nutation. Quite recently Professor HIROYAMA, of Tokio, has subjected the results of the first four years of the latitude variation results to a careful analysis, and reached the conclusion that the z-term is probably a result of errors which may be classified as instrumental. He did not include in his researches, however, the results from the southern stations.

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[1] The observations at Bayswater were discontinued in January, 1909; the station at Oncativo has been taken over by the Government of the Argentine Republic.

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[1] Later studies seem to indicate that the maxima and minima in the z-term are slowly shifting.

Probably no more marked case of modern specialization in the science of astronomy, no more fitting example of minute and careful analysis, nor any better illustration of the mutual interdependence of fields of investigation apparently widely separated, can be found than this same subject of the variation of latitude. Long since, Euler, from purely mathematical considerations with regard to a rotating spheroid, showed that the axis of the earth should be subject to a minute oscillation, with a period of 305 days. In 1890-91 Professor Küstner announced that this prediction had been confirmed by observation, but that the period was about 427 days. So minute is the movement that the poles shift from their mean position by less than thirty feet. Eight special observatories have been established, six in the northern hemisphere and two in the southern, and experienced observers are carefully accumulating the observations for the further study of this variation, determining from observations of the stars a periodic movement of the positions of the poles of the earth only a little greater than the distance from one wall of their small observatories to the other, and even showing, with some probability, that the earth's center of gravity oscillates once a year a distance of only a little over four feet toward one pole or the other. From these results Darwin, Hough, Larmor, and others have undertaken the investigation of the difference between the observed period of 427 days and that of 305 called for by theory, finding the explanation in the slight yielding of the earth, and have deduced the result that the earth, as a whole, must possess an effective rigidity a little greater than that of steel. In confirmation of these results, tidal students have found evidences, though very slight, of a minute tide with a period of 430 days. And in still another field these results may possibly prove of interest. No less an authority on earthquakes than Professor Milne has expressed the opinion that earthquakes are more frequent at those epochs when the axis of the earth is farthest from its mean position, though this theory is not accepted by most seismologists.

In the wide field of stellar photometry, a very large proportion of our knowledge of the southern stars comes from the results of the Harvard photometric expeditions and particularly from its station at Arequipa, Peru. Through the visual results secured at Córdoba, the photographic magnitudes as given by the Cape Photographic Durchmusterung, and the long series of exact visual estimations made with the meridian photometer at Arequipa, we may say that, except in certain special studies on the fainter stars, the state of our knowledge of the relative brilliancy of the stars of the southern hemisphere is not inferior to that of the northern hemisphere.

From this station, too, has come far the largest proportion of what is known to-day with reference to the variable stars in the more southerly regions of the sky. Epoch-making in this branch is the discovery by Professor BAILEY of a very large number of variable stars in clusters. The Magellanic Clouds and other clusters in the southern hemisphere have alone given about two thousand new variable stars; the determination of the periods of all these and the study of the peculiarities in their variation will in itself furnish work for many years to come. Much remains to be done as well on the brighter variable stars of the southern hemisphere.

Through the excellent work at Arequipa, also, Harvard's extensive spectrographic surveys have been extended to the south pole. While it is certain that future studies with spectrographs of higher dispersion will bring forth many new facts with regard to stellar constitution, there is no doubt that Harvard's extensive surveys of the entire sky in the photometric and spectrographic fields will for decades be to the astrophysicist what the Bonn Durchmusterung has been to the worker in the astronomy of position.

As in the surveys just mentioned, the spectrograph was at first employed solely to determine the constituent elements of the Sun and the stars, but the application of the Doppler-Fizeau principle to the determination of a star's velocity in the line of sight from its spectrum has opened up to astronomy a field so vast that we scarcely dare to-day even to demark its boundaries. Few are the fields of astronomical research where the work in radial velocities is not making itself felt, and to-day we are furnished with the interesting spectacle of the oldest astronomy of position and the newer astronomy of the spectrum drawing closer and closer together for the solution of problems of sidereal structure. In order to determine the motion of our Sun through space many analyses have been made of the minute proper motions of the stars across our line of vision, but all such determinations are subject to some uncertainty because of the fact that the true distances of the stars whose proper motions are used in the analysis are, in general, very imperfectly known. On the other hand, the spectrograph gives us the velocity of a star in the line of sight, a velocity which, in stars possessing good spectral lines, is accurate within a few tenths of a kilometer per second, and which is entirely independent of the distance of the star from our system. For this reason it should be possible to determine from the radial velocities of a considerable number of stars well distributed over the entire sky a much more accurate value of the amount and the direction of the movement of the solar system through space.

For a complete solution of this problem, at which Dr. CAMPBELL and his associates have been working during the past fifteen years, it was necessary that radial velocities he secured for the stars in the southern hemisphere. This need was laid before Mr. D. O. MILLS, who, in 1902, generously gave the funds necessary for the installation on Mount San Cristóbal, Santiago, Chile, of a 37-inch reflecting telescope with the necessary spectrographic equipment, and in 1905 advanced further funds to continue the southern work for five years longer.

Up to date about 6,200 spectrograms have been taken at Mt. Hamilton and 2,700 by the D. O. Mills Expedition at Santiago, on nearly 1,400 stars. The northern portion of the program is nearly completed, and two years more should see the southern portions of the work essentially finished, though decades could well be used in investigating the "by-products" which have appeared in the course of the work, and other decades for the much needed extension of these researches to fainter stars. To give one instance only, at the Santiago station alone forty-eight spectroscopic binaries have been announced up to May, 1909, and to work up these binary systems adequately and compute their orbits would necessitate at least three years' work. One in every five or six of the northern stars examined has proved to be a binary, and nearly one in five of the stars observed by Professor WRIGHT during the first two years and a half of the work of the D. O. Mills Expedition. The discovery of so many spectroscopic binaries has greatly complicated the problem of determining the solar motion; moreover, several other complexities have of late been added to the analysis of the results. Recent investigations of the proper motions of the stars made by KAPTEYN, EDDINGTON, DYSON, SCHWARZSCHILD, and others, have shown that our universe is probably complex rather than homogeneous in respect to its structure, for there seem to be at least two fairly well marked directions of motions among the stars as a whole. Moreover, MONCK and KAPTEYN have pointed out that a considerable majority of stars possessing marked proper motions belong to those spectral types which show numerous lines of various elements, while the hydrogen and helium stars are relatively fixed in space. In connection with these facts a further complexity is brought in on the spectroscopic side through the unfortunate circumstance that it is not possible to derive accurate velocities for many of the hydrogen and helium stars, because of the wide and hazy character of their spectral lines. A simple solution will then perhaps be insufficient, on the assumption that all the velocities arrange themselves according to the probability curve; it would seem that a satisfactory conclusion can only be reached by a very careful combination of spectrographic results with due regard to all that the astronomy of position can give us with reference to "star-drift," proper motions, and variation of proper motion with type of spectrum.

Work on the determination of radial velocities has recently been inaugurated at the Observatory of the Cape of Good Hope, so that these two observatories, that at the Cape, and the D. O. Mills Expedition, have to themselves this rich and still only partly explored field, while in the northern hemisphere some ten observatories are at work on problems more or less allied to the determination of radial velocities.

In Figure I are shown the location of the principal observatories of the world; the cut is that given by STROOBANT in *Les Observatoires Astronomiques et les Astronomes,* Bruxelles, 1907, with the addition of a few recently established stations. The map shows, better than any description or tabulation, the overwhelming disproportion in the number of astronomical foundations in the northern and southern hemispheres.

Sufficient has been said to point out the great richness of the skies of the southern hemisphere as a field for the working astronomer, and note has been made of some of the lines of work in which there are great untouched regions awaiting the explorer. Numerous other points in which there is need for work in southern skies could easily be pointed out. Much work still remains to be done by those who are not possessed of powerful instruments in the study of the brighter variable stars and meteor radiants. Excellent photographs have been made with the Bruce Refractor at Arequipa, but the field of southern nebular photography with reflecting telescopes is almost untouched as yet, and there is no more urgent need for the astronomy of the southern hemisphere than the establishment of a large reflector to continue for the southern skies the work done by ROBERTS, KEELER, PERRINE, and others on the northern nebulæ and clusters, for the study of faint variable stars, for parallax investigations, and many other allied lines of research. A program of nebular photography has been inaugurated with the new reflector at Helwan, Egypt; its southern limit, however, will extend only to — 40°. The day must come, also, when there shall be established at some favorable point in the southern hemisphere a large solar observatory to carry on solar studies and investigations of the Sun's constant of heat in the southern summer season, thus supplementing the work of the northern solar observatories.

Above all, so few are the workers in this southern field compared with the men and the instruments attacking the problems of the northern skies, that some scheme of co-operation among southern observatories seems imperative, each one to devote its attention to some one line of work or some definite zone. Professor COOKE, of Perth, has recently pointed out the disadvantages arising from scattered and unsystematic observations in meridian circle work, and has announced that for the future all the efforts of Perth Observatory in determining stellar positions will be concentrated upon the zone from south declination thirty-one to forty-one degrees. Some such plan of co-operation and delimitation seems essential for the future progress of astronomy, and more particularly for the astronomy of the southern hemisphere; as Professor KAPTEYN has pointed out, the scope of this science to-day, with its millions of isolated units demanding study, is too vast for the combined efforts of all the observatories of the world, and he has accordingly suggested the well-known plan of limiting future studies to certain relatively small "selected areas," a plan which promises to be the best method of extending our finite knowledge in a realm that is practically infinite.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1910.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter...	Jan. 3, $5^h 27^m$ A.M.	Last Quarter..	Feb. 2, $3^h 27^m$ A.M.
New Moon.....	" 11, 3 51 A.M.	New Moon....	" 9, 5 13 P.M.
First Quarter...	" 18, 2 21 A.M.	First Quarter..	" 16, 10 32 A.M.
Full Moon.....	" 25, 3 51 A.M.	Full Moon....	" 23, 7 36 P.M.

The Earth is in perihelion January 1st, 3^h A.M., Pacific time.

Mercury is an evening star until January 26th, 1^h A.M., when it passes inferior conjunction and becomes a morning star, remaining a morning star until early April. During the first half of January it will be a comparatively easy object for naked-eye view in the twilight soon after sunset, remaining above the horizon more than an hour, and at the time of greatest east elongation, January 10th, nearly an hour and one half after sunset. The greatest east elongation is rather a small one, as it occurs only eight days before the time of perihelion, and this makes